Indian J. Phys. **71B** (1), 113–116 (1997)

NOTE

IJP B
- an international journal

New interferometer based on division of wavefront

Rahimuddin
Department of Physics, Aligarh Muslim University,
Aligarh-202 002, India

Received 19 August 1996, accepted 22 November 1996

Abstract : An interferometer based on division of wavefront has been made. In Young's double slit setup, a new scanning device is introduced to change the path difference of the interfering beams. The setup can work as interferometer to study the temporal as well as spatial coherence.

Keywords : Light interference, light interferometry.

PACS Nos. : 07 60.Ly, 42.25.Hz

The interference pattern between the two samples of the same wavefront gives a measure of spatial coherence. The measurement is accomplished with the help of Young's double slit experiment. The spectral analysis of light in the region of superposition provides the information about the spectral coherence properties of the light incident on the two slits [1]. The Young's double slit setup can be used to study mutual coherence, complex degree of coherence and cross spectral density. The coherence function provides us information about the source, fields and statistical description of fields, without considering origin and growth of coherence within the source itself. We can also describe the properties of free fields [2].

An interferometer which is based on division of wavefront of light has been made. The wavefront can be divided by using double slits. Improvement of some mechanical arrangements of Young's double slit experiment with the additional degree of freedom to select the time between the interfering beams can be made with the help of a moving mirror and a fixed mirror.

In this way, a time lag can be created in the two interfering beams, emerging from the two slits. It has been tried to collect all the characteristic features of Young's double slit experiment in the interferometer. The additional degree of freedom of time will enable us to know the wave lengths of the source.

© 1997 IACS

The basic interference law in given by :

$$I(r) = I_1(r)+I_2(r)+2[I_1(r).\ I_2(r)]^{1/2}.\ Be[\gamma(r_1,r_2,\tau_{12})], \tag{1}$$

where $\tau_{12} = (R_1 - R_2)/c = (PP_1 - PP_2)/c$

$I(r)$ average light intensity at point P specified by a position vector r on the screen B_1, $I_1(r) = \Gamma(r, r, 0)$ represents the average intensity of light if only the pin hole/slit at P_1 is open; c is the speed of light and $I_2(r)$ has similar interpretation. The slits are located at P_1 and P_2 while γ represents the complex degree of coherence.

This law of interfernce (1) for partially coherence beam provides no information about the spectral composition of light forming the interference pattern [3].

We consider two beam interfernce experiment because of the dispersive effect associated with diffraction. It is also simpler to relate fields at $P(r)$ to the fields at $P_1(r_1)$ and $P_2(r_2)$.

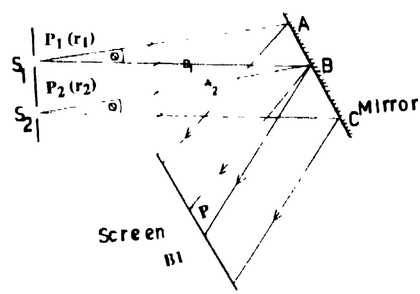

Figure 1. Reflection of interference pattern on screen

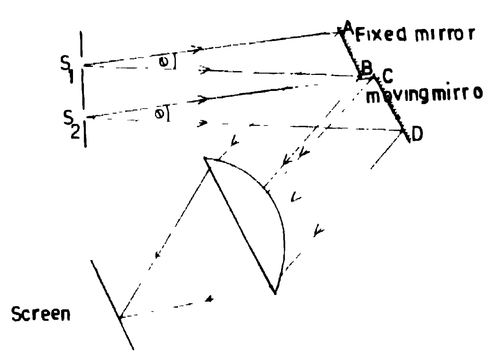

Figure 2. New interferometer

The spectral density of light at a typical point r on the screen B_1 is

$$W(r,r,\nu) = W_1(r,r,\nu)+W_2(r,r,\nu)+2[W_1(r,r,\nu)W_2(r,r,\nu)]^{1/2} \times \mathrm{Re}\{\mu(r_1,r_2,\nu)\exp[i\alpha - 2\pi i\nu(R_1 - R_2)/c]\} \tag{2}$$

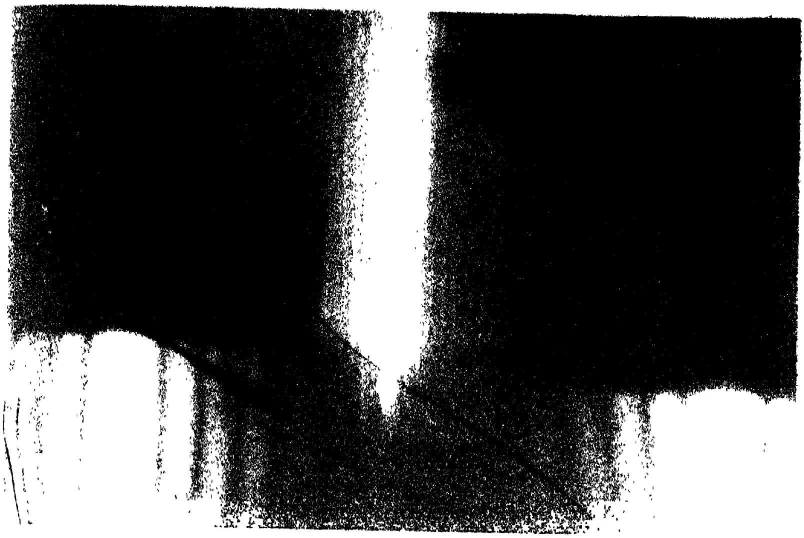

Figure 3. Fringe pattern for the path difference of ~1.6 cm.

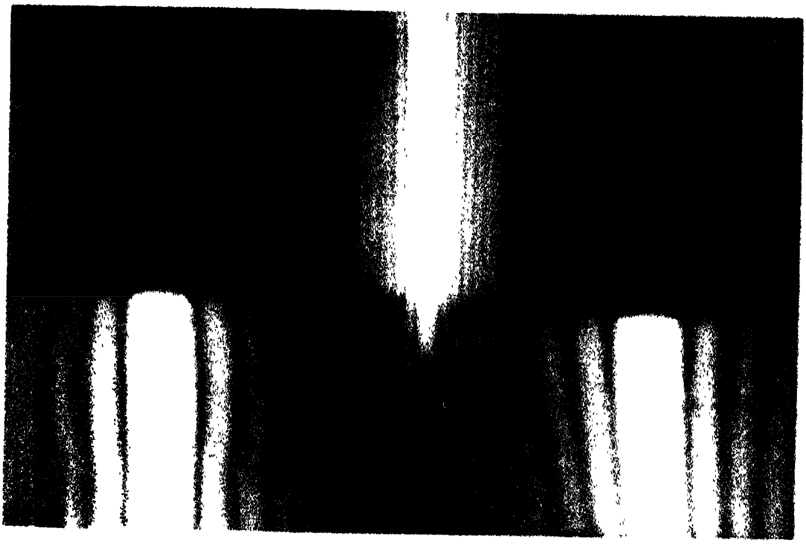

Figure 4. Fringe pattern for the path difference of ~0.3 cm.

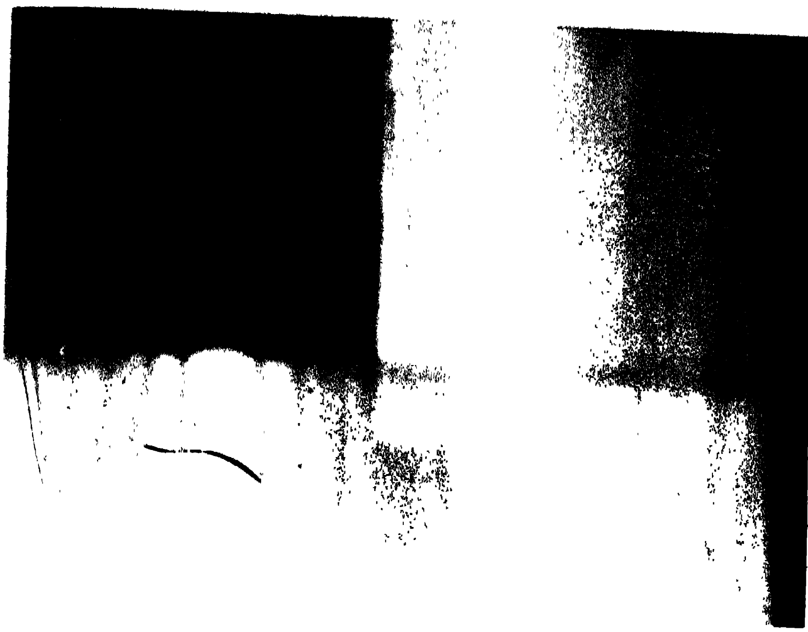

Figure 5. Fringe pattern for the path difference of ~0.6 cm.

The eq. (2) shows that in general, the spectral density of light at P (r) is not just the sum of the spectral densities of the two beams reaching the point from the two pin hole/slit, but differ from it by a term depending on the complex degree of the spectral coherence $\mu(r_1, r_2, \nu)$ of the light at the two pin holes/slits.

The eq. (2) is the spectral interference law for partially coherent beams. The spectral interference law may also be considered as expressing the energy distribution as a function of frequency in the interference pattern obtained by the superposition of the light from the two pin holes/slits.

The single slit :

The angular width $2\lambda/b$ of principal maximum of the diffraction pattern of a single slit of width b is illuminated by wavelength λ, while lateral width of the beam W at a distance L on screen is $2l\lambda/b$.

The double slit :

The double slit diffraction pattern can be thought as, if we brought two slits at a separation of d to produce interference pattern between the beams emerging from the slits. The extreme ray A_2 of slit S_2 intercept the ray B_1 of slit S_1, making an angle θ *i.e.* $2\lambda/b$. Similar assumption may be valid for different parts of beams emerging from slits S_1 and S_2 of same wavelength and phase. In Figure 1, a mirror is shown which is placed at a certain angle to divert the diffraction pattern to a screen placed parallel to the mirror. The double slit interference pattern of the monochromatic light, consists of fringes of fringe width $\beta = \lambda D/d$ and intensity $I = 4I_0 \cos^2 \delta/2$ where $\delta = 2\pi/\lambda\,(S_2P - S_1P)$ with maxima at $(S_2P - S_1P) = n\lambda$ and minimum at $(S_2P - S_1P) = (n + 1/2)\lambda$.

The outline geometry of the experimental setup is shown in Figure 2. Two slits of equal widths S_1 and S_2 are illuminated by using a murcury (Hg) are source and a Jarell Ash 0.25 m monochromator to select the 5460 Å Hg line. The interfering beams will have the same angular width. Two mirrors AB and CD (parallel and close to each other) are placed just before the intercepting point of the two beams. Away from this point, two divergent beams from the two slits, start overlapping. The mirror AB and CD make obtuse angles with the perpendiculars drawn on the slits. The mirror AB and CD reflect and divert the emerging beams from the two slits separately. A plano-cylindrical lens parallel to the mirrors AB and CD will show the interference pattern of the two beams at its focus. Keeping the mirror AB fixed, the mirror CD can be moved perpendicular to the slits plane in a straight line. The movement of the mirror CD would create the path difference between the two interfering beams.

In this setup, some parts of the reflected beams from the fixed and moving mirrors were passed through the plano-cylindrical lens, to be focussed on the screen and the remaining part of the beams were passed under the lens to get an unfocussed beams on the same screen. In this way, the superimposed beams and the reflected beams can be recorded on the same screen simultaneously. When the moving mirror create large path difference

(15 mm), few fringes with less contrast were observed [Fig. 3]. On reducing the path difference (8 mm), the visibility of the fringes gets improved [Fig. 4]. Lastly, we recorded the fringes pattern for the least possible path difference (6 mm) in our setup, in which the number of fringes and the visibility further improves [Fig. 5].

In this interferometer, which is based on division of wavefront with a moving mirror device to create the path difference between two interferring beams, it was found that when the moving mirror is close to the fixed mirror (small path difference ~6 mm), the fringe contrast is better than that observed with the large path difference (1.5 mm). The visibility and the number of the fringes reduce for large path difference.

Acknowledgments

The keen interest, suggestions and discussions with Prof. B N Khanna is gratefully acknowledged. I am thankful to Prof. Y Kumar for providing laboratory facility and guidance throughout the experimental work. The author is also thankful to Prof. J H Naqvi, Chairman of the Department of Physics, A.M.U., Aligarh and Prof. Javed Husain, Department of Applied Physics, A.M.U., Aligarh for encouragement and cooperation. The cooperation of Mr. Siddique Akbar is also thankfully acknowledged.

References

[1] Robert D Guenther *Modern Optics* (New York : John Wiley and Sons) (1990)

[2] L Mandel and E Wolf *Rev. Mod. Phys* 37 231 (1965)

[3] L Mandel and E Wolf *J Opt Soc Am* 66 529 (1976)